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Wood Density Surveys of the Minor Species of Yellow Pine in the Eastern United States

Part II--Sand Pine (Pinus clausa (Chapm.) Vasey)

by

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INTRODUCTION

This report is the second of a series covering wood density surveys of the minor species of yellow pine in the Eastern United States.' Literature review and historical information regarding these surveys were presented in "Part I-Spruce Pine (Pinus glabra Walt.)" by Taras and Saucier (1968) and will not be repeated here.

The objectives of the survey were:

- (1) To obtain data that will provide an estimate of the average specific gravity of unextracted and extracted wood of each minor species, and establish the degree of variation about each mean.
- (2) To evaluate increment core/tree specific gravity relationships and develop regression equations for predicting tree specific gravity from increment core specific gravity.
- (3) To examine the geographic trends of wood specific gravity within the range of each species, from east to west and from north to south.

MATERIALS AND METHODS

Species

Sand pine (Pinus clausa (Chapm.) Vasey), also called scrub pine or spruce pine, is the only species discussed in this report. Harlow and Harrar (1950) describe sand pine as a small tree, of poor form (fig. 1A), commonly found on slightly acid, sterile sandy soils in Florida and characterized by narrowly ovoid-conic cones which are often persistent for many years or until opened by the heat of a forest fire. The scientific name clausa, meaning closed, refers to this feature. The needles are about 3 inches long, slender, flexible, and in fascicles of two (fig. 1B). The bark is comparatively smooth, becoming plated only on the lower trunks and large branches (fig. 1C). In the crown part of the trunk the bark is orange-brown and appears to blister and have curly flakes (fig. 1D). Except for a small area in southeastern Alabama, the range of this species is confined to Florida (fig. 2).

Two races of this species have been named by Little and Dorman (1952). They proposed the name "Ocala sand pine" for the race with closed cones growing in eastern Florida and "Choctawhatchee sand pine" for the race having open or normal cones and growing in western Florida. Ocala sand pine forms even-aged, single species forests of narrow, pointed trees, 20 to 50 feet high. It grows most extensively on the Ocala National Forest in

¹This study was conducted in cooperation with the Forest Products Laboratory, the Northeastern Forest Experiment Station, the Southern Forest Experiment Station, and state forestry services, the pulp and paper industries, the southern pine plywood and sawmill industry, and numerous private forest owners throughout the Southern and Eastern United States.

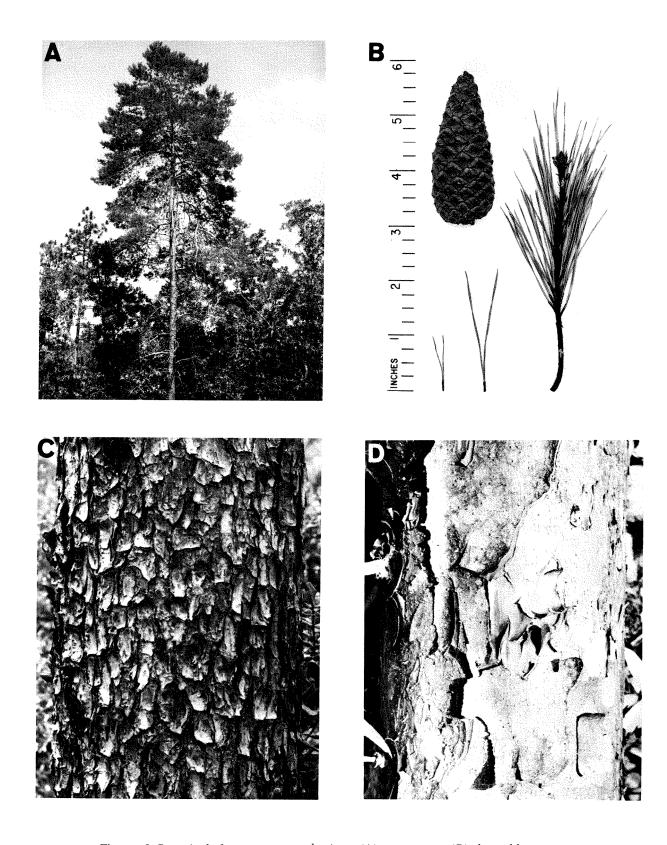
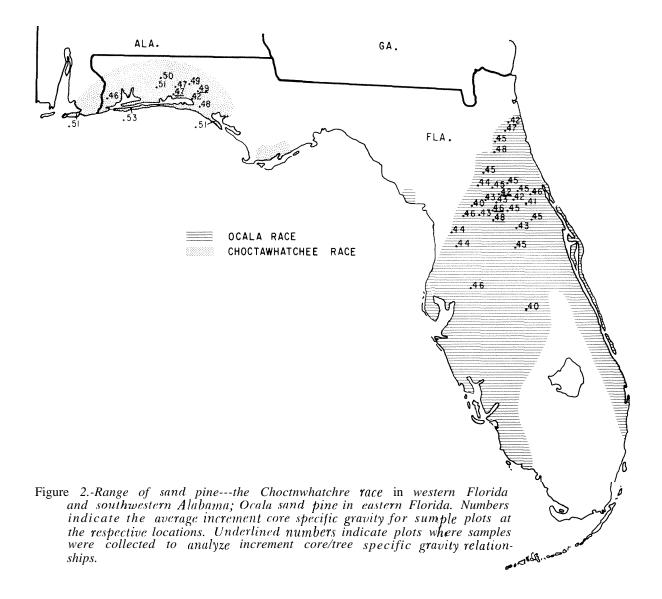


Figure I.-Botanical features of sand pine: (A) tree form; (B) branchlet, cones, nnd needles; (C) bark of mature tree; (D) young bark on upper bole and brunches of a mature tree.



north-central Florida, where it covers about 280,000 acres. The Choctawhatchee sand pine forests, on the other hand, consist of uneven-aged stands mixed with small amounts of scrub oaks, including live oak (Quercus virginiana var. geminata (S m a 11) Sarg.), turkey oak (Q. laevis Walt.), and myrtle oak (Q. myrtifolia Willd.).

Forest Survey Release No. 57 by Larson and Goforth (1961) lists the total predicted commercial forest land supporting sand pine in Florida as 422,000 acres. Oeala sand pine occurs on 374,000 acres while Choctawhatchee sand pine is found on only 48,000 acres. The total standing volume of timber indicated by Forest Survey is approximately 90 million cubic feet of wood—about 80 million cubic feet of Ocala and 10 million cubic feet of Choctawhatchee.

Field Sampling Procedure

To meet the objectives of the study, 35 plots were sampled throughout the **range** of the species. Ocala sand pine was sampled at 25 locations throughout its range and Choctawhatchee was sampled at 10 locations. We calculated the number of trees per plot had to be 20, in order to obtain an estimate of the mean wood density with a 95 percent confidence interval width of .02. With the 3.03 diopter prism, a sufficient number of sampling points were selected (using random azimuths and distances between points) so at least 20 trees could be sampled at each plot location. The total number of trees sampled was '716. The plots were selected randomly, with replacement, with the probability roughly proportional to the volume of the species

within Forest Survey Units ² containing sand pine. A 6-mile grid system was used to locate plots randomly within survey units.

Two increment cores were removed from opposite sides of each sample tree. Cores were stored in a 4-percent solution of formaldehyde immediately after being removed from the tree and were shipped green to the laboratory. The total height, merchantable height to a 4-inch top, and d.b.h. of each sample tree were sampled.

The trees to be used for analyzing increment core/tree specific gravity relationships were randomly selected at two locations within the range of the Choctawhatchee race and at three locations within the range of the Ocala race (fig. 2). Two increment cores were taken from each of 25 to 34 trees at each location before they were felled. Beginning at the butt end of the tree, l-inch-thick disks were cut at 5-foot intervals to a 4-inch top. Total height and merchantable height to a 4-inch top of each tree were recorded, as was the diameter of each disk.

Laboratory Procedures

The specific gravity of all increment cores was determined in the unextracted and extracted condition by the maximum moisture method described by Smith (1954). All cores were subjected to a vacuum treatment for several days to insure complete water saturation. Wood disks were soaked for several days and their specific gravities determined by the buoyancy method described by Heinrichs (1954). The results are based on green volume and ovendry weight.

Increment cores from all trees were extracted after unextracted specific gravity was determined. Extractions were made with a mixture of two parts benzene and one part ethyl alcohol for 24 hours. Following extraction, the cores were saturated with water, and their specific gravity determined by the maximum moisture method. No wood disks were extracted.

From the sample of trees collected to analyze increment core/tree specific gravity relationships, each increment core was divided into three equal parts and specific

gravity determined for each segment. The purpose was to obtain a weighted increment core specific gravity, and to examine the relationship of parts (1/3 and 2/3 only of increment cores to total tree specific gravity. Weighted total core specific gravity was determined by weighting the specific gravities of segments by the cross sectional areas the segments represented.

Average specific gravity of the individ ual 5-foot bolts within each tree wa computed as the mean of the bolt's termina disks. The average specific gravity of the tree was determined by weighting the average bolt specific gravity by bolt volume Formulas for all these computations art shown in the Appendix. A discussion of the analysis of the increment core/tree specific gravity relationship data is presented in an office report available from the Forestry Sciences Laboratory, Carltor Street, Athens, Georgia 30601.

RESULTS AND DISCUSSION

Sand Pine Specific Gravity and Its Variation

The average specific gravity of unextracted Ocala sand pine increment cores was .439, based on the average of two whole increment cores from each of 523 sample trees collected over the entire range of the race. The standard error of the mean increment core specific gravity was ,004, and the standard deviation about the mean of the individual observations was .037. Choctawhatchee sand pine had an average unextracted increment core specific gravity of .485, based on two whole cores from each of 193 sample trees. The standard error was .003, and standard deviation of individual observations was .045.

The average specific gravity of extracted increment cores from Ocala sand pine was .407; standard error was .004 and standard deviation of individuals was .030. Extracted increment cores of Choctawhatchee sand pine had an average specific gravity of .442, with a standard error of .003 and a standard deviation of .032 for individual observations. Specific gravity of unextracted Ocala sand pine increment cores was 7.86 percent higher than the extracted increment core specific gravity; the unextracted specific gravity of Choctawhatchee sand pine increment cores was 9.73 percent higher than the extracted specific gravity. Both races of sand pine contain a large amount of extractives, compared to the four major southern yellow pines which

²Forest Survey Units are subdivisions of a state based in part on county boundaries and in part on the physiography of the state. They are established for the purpose of sampling and reporting results efficiently.

normally contain 6.0 to 7.5 percent extractives (Taras and Saucier 1967).

Extracting Choctawhatchee increment cores reduced the standard deviation of individuals about the mean from .045 to .032, which compares favorably with the standard deviation of extracted Ocala increment cores (.030). The average specific gravity of unextracted and extracted increment cores for both races is shown in table 1.

Analysis of variance showed that specific gravities of unextracted and extracted increment cores from Choctawhatchee sand pine were significantly higher than those

of Ocala sand pine at the .001 probability level (table 2). The difference in average specific gravity of unextracted increment cores between the two races lies within the confidence interval : P $[.034 \le \mu \le .058\] = .999$. One reason for this difference in increment core specific gravity might be that Choctawhatchee trees averaged 9 years older than the Ocala trees, and thus contained a smaller proportion of juvenile wood of low specific gravity. This difference in age could be important because the Ocala trees sampled averaged only 25 years (table 1).

The average unextracted tree specific gravity for Ocala sand pine was computed with the following regression equation :

Table 1.—Specific gravity of unextracted and extracted increment cores from Ocala and Choctawhatchee sand pine

			OC	ALA SAN	ID PINE				
					Unextr	acted	Extra	cted	
					Mean and		Mean and		Difference
Plot	County and	Trees in	Mean	Mean	standard	Standard deviation	standard	Standard	between
number	state	sample	d.b.h.	age	error	deviation	error	deviation	means
		Number	Inches	Years	165 (00G)	.028	499 / OOES	000	Percent
1	St. Johns, Fla.	20 21	7.4 11.39.1	28	.465 (.006) .479 (.012)	.028	.433 (.007) .429 (.008)	.030 .034	7.39 11.65
2 3	Clay, Fla. Putnam, Fla.	21	14.42.1	24 30	.451 (.008)	.036	.423 (.008)	.034	6.62
4	St. Johns. Fla.	22	1.6 1.1	20	.416 (.006)	.026	.395 (.005)	.024	5.32
5	Marion, Fla.	• •		36	.450 (.007)	.032	.424 (.006)	.030	6.13
6	Marion, Fla.	21		34	.443 (.006)	.029	.418 (.006)	.028	5.98
7	Marion, Fla.	26	89 89	30	.434 (.007)	.037	.408 (.006)	.031	6.37
8	Volusia, Fla.	20	8.3	22	419 (.007)	.034	.397 (.007)	.033	5.54
9	Volusia, Fla.	20	10.68.5	24	.448 (.009) .459 (.010)	.040 .044	.414 (.008) .419 (.008)	.034 .037	8.21
10 11	Volusia, Fla. Volusia. Fla.	20	8.4	31 18	.412 (.007)	.032	.391 (.007)	.029	9.55 5.37
12	Marion, Fla.	20	8.6	34	.446 (.008)	.036	.415 (.007)	.029	7.47
13	Marion, Fla.	21	7.8	42	.454 (.007)	.034	.429 (.007)	.034	5.83
14	Marion, Fla.	20	6.7	16	.400 (.009)	.038	.369 (.004)	.019	8.40
15	Marion, Fla.	23	5.7	28	.430 (.007)	.032	.404 (.006)	.028	6.70
16	Marion, Fla.	20	8.9	28	.451 (.008)	.037	.423 (.008)	.037	6.62
17	Citrus, Fla.	22	8.0	25	.442 (.008)	.036	.412 (.005)	.025	7.28
18	Marion, Fla. Marion, Fla.	$\begin{array}{c} 20 \\ 20 \end{array}$	10.8	20 29	.416 (.009)	.042	.382 (.007)	.032 .038	8.90
19 20	Seminole, Fla.	20	11.1 12.3	18	.435 (.009) .434 (.010)	.042 .044	.406 (.008) .393 (.007)	.029	7.14 10.43
21	Volusia, Fla.	20	8.0	20	.445 (.007)	.032	.408 (.008)	.036	9.07
22	Lake, Fla.	20	0.6	18	.453 (.010)	.044	.413 (.011)	.049	9.69
23	Hernando, Fla.	20	10.5	22	.441 (.008)	.036	.401 (.007)	.030	9.98
2 4	Hillsboro, Fla.	20	10.6	2 1	.459 (.010)	.046	.412 (.008)	.037	11.41
25	Polk, Fla.	21	6.2	14	.402 (.008)	.035	.368 (.005)	.024	9.24
	Total	523	8.8	25	.439 (.004)	.037	.407 (.004)	.030	7.86
		CH	OCTAW	HATCHE	E SAND	PINE			
	Franklin, Fla.	33	7.1	29	.505 (.006)	.035	.462 (.005)	.030	9.31
2	Walton, Fla.	21	9.3	29	.479 (.007)	O.I.Im	.449 (.006)	.027	6.68
3	Walton, Fla.	24	6.9	17	.416 (.003)	.017	.395 (.004)	.018	5.32
4	Walton, Fla.	21	11.4	31	.469 (.005)	.024	.424 (.004)	.020	10.61
5 6	Walton, Fla. Walton, Fla.	21 19	10.8 9.5	3 4 3 2	.496 (.010) .491 (.006)	.047 .026	.435 (.009)	.041 .017	12.98 12.87
7	Okaloosa, Fla.	20	12.2	48	.506 (.007)	.030	.466 (.006)	.027	8.58
8	Santa Rosa, Fla.	8	9.3	37	.528 (.020)	.057	.459 (.008)	.023	15.03
9	Escambia, Fla.	ő	10.6	37	.463 (.013)	.031	.435 (.009)	.021	6.44
10	Baldwin, Ala.	20	9.6	4 4	.509 (.013)	.057	.460 (.008)	.036	10.65
	Total	193	9.7	34	.485 (.003)	.045	.442 (.003)	.032	9.73

Tree specific gravity (Y) = 0.26222 + 0.56947 (sp. gr., 2 extracted cores) -0.19747 (d.b.h./age) (1)

When the specific gravity of the 523 Ocala sand pine trees sampled by increment cores was adjusted to whole tree specific gravity by using equation (1), the

Table 2.—Analyses of variance of increment core specific gravity for Ocala sand pine and Choctawhatchee sand pine

		Uncx	tracted	Extracted		
Source	d.f.	MS	F ratio	MS	F ratio	
Between races Within races Total	1 714 715	0.2972 0.0017	174.82***	0.1720 0.0012	143.33***	

^{***}Significant at the .001 probability level.

average unextracted tree specific gravity was .419, with a standard error of .003.

The average unextracted tree specific gravity for Choctawhatchee sand pine tree; was computed with the following regres sion equation:

Tree specific gravity
$$(Y) = 0.14879 + 0.78915$$
 (sp. gr., 2 extracted cores)
- 0.05552 (d.b.h./age) (2)

When the increment core specific gravity of the 193 Choctawhatchee trees sampled was adjusted by using equation (2), the average unextracted tree specific gravity was .482, with a standard error of .008.

The specific gravities of unextracted increment cores by diameter classes (5.0 to 8.9 inches; 9.0 to 14.9 inches; and 15.0+inches) are shown in table 3 for each Forest

Table 3.-Specific gravity data for Ocala and Choctawhatchee sand pine by states and by Fores Survey Units within states

			OCALA	SAND PINE			
State, survey unit, and number	Locations sampled	Diameter class	Trees sampled	Unextracted i core specific Mean and standard error	gravity Standard deviation	Estimated tree specific gravity! mean and standard error	Approx. timber volume2
	Number	Inches	Number			1	Million
Florida							cu. ft.
Northeast (1)	19	5.0-8.9 9.0-14.9 15.0+	254 136 10	.438 (.005) .441 (.006) .449 (.018)	.034 .043 .065	.437 (.003) .418 (.005) .379 (.017)	42.4 18.0 0.9
Central (3)	6	5.0-8.9 9.0-14.9 15.0+	68 44 11	.425 (.008) .452 (.008) .465 (.003)	.048 .041 .054	.397 (.008) .385 (.010) (3)	13.0 5.1 0.1
State total	25	5.0-X.9 9.0-14.9 15.0+	322 180 21	.435 (.004) .444 (.005) .458 (.003)	.035 .041 .056	.433 (.003) .403 (.006) (3)	55.4 23.1 1.0
Total all classe	s 25		523	.439 (.004)	.037	.419 (.004)	79.5
		CHC	OCTAWHAT	CHEE SAND	PINE		
Alabama Southwest (1)	1	5.0-8.9 9.0-14.9 15.0+	9 11 0	.501 (.019) .515 (.017)	$.057 \\ .056 \\ 0$.502 (.011)	- Children
Florida Northwest (2)	9	5.0-8.9 9.0-14.9 15.0+	90 72 11	.480 (.020) .484 (.006) .489 (.009)	.053 .037 .057	.480 (.004) .478 (.005) .472 (.012)	8.8
Total both state	es 10	5.0-8.9 9.0-14.9 15.0+	99 83 11	.482 (.018) .488 (.005) .489 (.009)	.053 .056 .057	.482 (.004) .481 (.005) .472 (.012)	8.8
Total all classe	es 10		193	.485 (.003)	.045	.482 (.003)	9.9

¹Estimates were made using equation (1) for Ocala and equation (2) for Choctawhatchee sand pine.

²From Forest Survey data of the Southern and Southeastern Forest Experiment Stations.

³The mean d.b.h./age ratio for the 15.0+ inch diameter class lies outside the range for which equation (1) can be used with confidence to estimate tree specific gravity.

Survey Unit sampled. In table 3 the estimated tree specific gravity and standard error for Ocala sand pine have been omitted for the 15.0+ inches diameter class for both the Central Survey Unit and the state total. This deletion was necessary because the average tree sampled only by increment cores represents a population growing much faster than the 84 trees used to develop the regression equation for Ocala sand pine. The 15.0+ class trees in the Central Survey Unit had an average d.b.h./ age ratio of ,779, and ranged from .410 to 1.069; the trees used to develop the regression equation had an average d.b.h./age ratio of .240 with a standard deviation of 0.121, and ranged from .110 to .600 (table 4). Since the mean d.b.h./age ratio for the 15.0+ class falls outside the range of the d.b.h./age data used to develop the regression equation, little confidence can be placed in estimates of tree specific gravity in that class. Equation (1) should not be used for estimating tree specific gravity for trees growing faster than .6 inch per vear.

The estimated tree specific gravity data shown in table 3 are reproduced in figure 3 to illustrate the distribution of diameter

classes and their specific gravities within each Forest Survey Unit.

Geographic Variation

The data in table 1 are also shown in figure 2 to illustrate specific gravity changes with geographic location. In figure 2 there appear to be no geographic trends from north to south or east to west except for the previously noted difference between races-Choctawhatchee growing in west-ern Florida and Ocala in eastern Florida. There appears to be little change in specific gravity over the entire range of each race, compared to some of the major yellow pines. This relative uniformity in specific gravity may result because sand pine grows on restricted sites and not over a wide variety of sites and moisture conditions. The differences in specific gravity which occur between plots (figure 2) were not extremely large (maximum difference between plots for Ocala sand pine was .08 and for Choctawhatchee was .11), but were statistically significant at the .001 probability level. Analyses of variance showing mean squares and F ratio are presented in table 5.

Table 4.-Mean and standard deviation of the dependent and independent variables used to develop regression equations for the increment core/tree specific gravity relationships for Choctawhatchee and Ocala sand pine

	Choctav	whatchee		Ocala		
Variables	Mean	Standard deviation	Mean	Standard deviation		
Dependent						
Weighted tree specific gravity	0.475	0.029	0.451	0.042		
Independent						
D.b.h.	10.776	3.711	8.720	2.776		
Total height	54.370	7.783	51.262	10.414		
Age	44.074	9.572	41.988	13.825		
Merchantable volume	16.667	11.551	11.131	9.795		
D.b.h./age	0.246	0.072	0.240	0.121		
l /age	0.024	0.005	0.029	0.016		
Merchantable volume/age	0.36.	0.219	0.268	0.198		
Total height/age	1.277	0.279	1.363	0.484		
Specific gravity, 1 core	0.475	0.036	0.448	0.037		
Specific gravity, outer 2/3 of 1 core	0.488	0.040	0.467	0.042		
Specific gravity, outer 1/3 of 1 core	0.492	0.05 1	0.467	0.049		
Specific gravity, 2 cores	0.481	0.033	0.450	0.038		
Specific gravity, outer 2/3 of 2 cores	0.493	0.032	0.472	0.044		
Specific gravity, outer 1/3 of 2 cores	0.496	0.041	0.476	0.048		
Weighted specific gravity, 1 core	0.485	0.039	0.461	0.040		
Weighted specific gravity, 2 cores	0.490	0.033	0.466	0.042		
Specific gravity, 1 extracted core	0.425	0.027	0.413	0.033		
Specific gravity, outer 2/3 of I extracted core	0.447	0.032	0.434	0.036		
Specific gravity, outer 1/3 of 1 extracted core	0.453	0.046	0.435	0.041		
Specific gravity, 2 extracted cores	0.430	0.026	0.414	0.031		
Specific gravity, outer $2/3$ of 2 extracted cores	0.451	0.030	0.437	0.034		
Specific gravity, outer 1/3 of 2 extracted cores	0,461	0.039	0.441	0.038		
Weighted specific gravity, 1 extracted core	0.441	0.032	0.427	0.034		
Weighted specific gravity, 2 extracted cores	0.446	0.029	0.430	0.033		

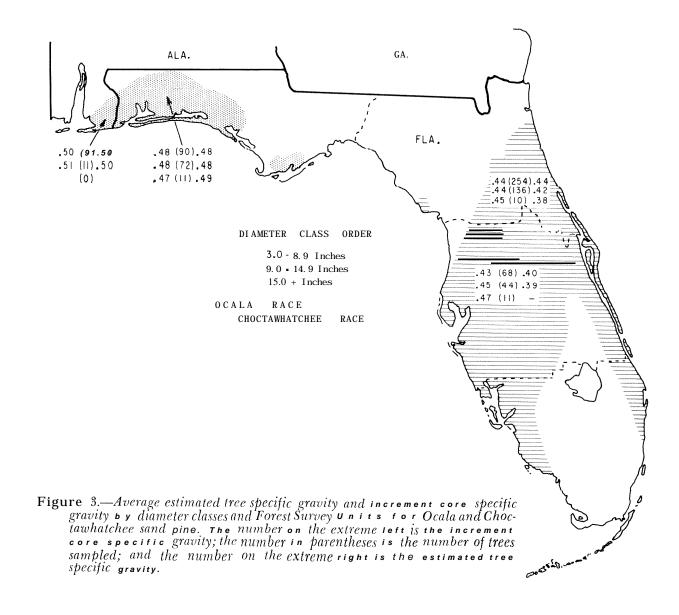


Table 5.—Analyses of variance for Ocala and Choctawhatchee sand pine specific gravity and test of significance for locations

CHOCTAWHATCHEE SAND PINE

		Une	extracted	Ex	Extracted		
Source	d.f.	M S	F ratio	MS	F ratio		
Among locations Within locations Total	9 183 192	0.0160 0.0013	12.3070***	0.0091 0.0008	11.3750***		
		OCALA S	AND PINE				
Among locations Within locations Total	24 498 522	0.0080 0.0013	6.1538***	0.0062 0.0010	6.2000***		

^{***}Significant at the .001 probability level.

Increment Core /Tree Specific Gravity Relationships - Linear and Multiple Regression Analyses

Discussions of the increment core/tree specific gravity relationships are covered in an office report available upon request and will not be covered in detail here. The simple and multiple regression equations developed by the analysis of these relationships are given in tables 6 and 7 in the Appendix, and are listed in order of their relative predicting precision.

Equations (1) and (2) used to adjust the specific gravities of increment cores to tree specific gravities are not the best equations, as shown in tables 6 and 7. Equations (1) and (2) were used instead of the best equations for economic reasons. The increment cores collected in the survey were not segmented when specific gravity was determined. The time and increased cost in obtaining weighted specific gravity values for segmented cores was not warranted since loss in predicting precision was not too great if equations (1) and (2) were used. The equations used had a correlation coefficient of .85 for Ocala sand pine and .75 for Choctawhatchee. The independent variables in equation (1) are associated with 72 percent and in equation (2) with 56 percent of the variation in tree specific gravity. These associations are only 7 percent and 2 percent less than the best equations developed.

Relationship of Unextracted to Extracted Specific Gravity

The specific gravity of all increment cores was determined in both the unextracted and extracted condition. A linear regression was used to analyze these data for each race. The results show that in both races the same high correlation (r = .88) esists for the specific gravity relationship between unextracted and extracted increment cores. In the following equations, the unextracted increment core specific gravity is associated with 77 percent of the total variation in extracted increment core specific gravity:

$$Y = 0.11681 + 0.67118 X,$$
 (3)

Where Y extracted increment core specific gravity of Ocala sand pine

X₁ unestracted increment core specific gravity of Ocala sand pine

$$Y = 0.07015 + 0.76807 X,$$
 (4)

Where Y = extracted increment core specific gravity of Choctawhatchee sand pine

 $X_1 = \text{unextracted}$ increment core specific gravity of Choctawhatchee sand pine

Taras and Saucier (1968) found the same high correlation for the specific gravity relationship between unextracted and extracted increment cores in spruce pine.

As mentioned earlier, specific gravity of unextracted cores of Ocala sand pine was 7.86 percent higher than that for extracted increment cores, and specific gravity of unextracted cores of Choctawhatchee sand pine was 9.73 percent higher than the extracted specific gravity.

SUMMARY AND CONCLUSIONS

The average specific gravity of Ocala sand pine increment cores taken at d.b.h. was .439, while Choctawhatchee sand pine averaged .485. Extraction reduced specific gravity of increment cores from Ocala sand pine to .407, a difference of 7.86 percent. Extraction reduced the specific gravity of increment cores from Choctawhatchee sand pine from .485 to .442, a difference of 9.73 percent. This indicates Choctawhatchee sand pine contains more extractives than any other eastern yellow pine examined in this laboratory.

Equations are presented for predicting specific gravity of extracted increment cores from the specific gravity of unextracted increment cores from both races. In both equations, the specific gravity of unextracted increment cores is associated with 77 percent of the total variation in specific gravity of extracted increment cores.

The specific gravities of unextracted and extracted increment cores of Choctawhatchee sand pine were significantly higher than those of Ocala sand pine. The difference in average specific gravity of unextracted increment cores between the two races lies within the confidence interval : $P[.034 < \mu < .058] \equiv .999.$ There appear to be no distinct north-south **or** east-west geographic trends in specific gravity within the range of either race.

The best equation developed for Ocala sand pine involved three independent variables: (1) weighted specific gravity of two extracted cores, (2) d.b.h./age, and (3) d.b.h. These variables were associated with 79 percent of the total variation in tree The best equation for gravity. Choctawhatchee sand pine involved: (1) weighted specific gravity of two unextracted cores, (2) total height, and (3) d.b.h./ age. These variables were associated with 58 percent of the total variation in tree specific gravity. The following equations were used to adjust increment core specific gravity values to tree specific gravity because the increment cores taken in the survey were not segmented when their

specific gravities were determined :

Y = 0.26222 + 0.56947 (sp. gr., 2 extracted cores) — 0.19747 (d.b.h. age) (1

Y = 0.14879 + 0.78915 (sp. gr., 2 extracted cores) -0.05552 (d.b.h. age) (2

Equation (1) was used to adjust Ocal sand pine increment core specific gravit to tree specific gravity and explained 7 percent of the variation. Equation (2) wa used to adjust Choctawhatchee sand pin increment core specific gravity to tree specific gravity and explained 56 percent of the variation.

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APPENDIX

Computational Procedures

1 Increment core specific gravity = ovendry weight of core green weight of core .3464 (ovendry weight of core)

- 2 Disk specific gravity = ovendry weight of disk displaced volume of disk
- 3 Bolt specific gravity = specific gravity top disk + specific gravity bottom disk
- 4 Tree specific gravity = $\frac{\sum\limits_{1-n}^{\sum} \text{(bolt volume } x \text{ bolt specific gravity)}}{\sum\limits_{1-n} \text{bolt volumes}}$
- 5 Bolt volume = bolt length, feet $\mathbf{x} \left[\frac{.005454 \, (d.i.b.)_{t}^{2} + .005454 \, (d.i.b.)_{b}^{2}}{2} \right]$ where: $t \ge top of bolt$
- 6 (a) Mean core specific gravity $\frac{\sum_i \sum_j X_{ij}}{m_1^2 n_1^2}$

b = base of bolt

where: X_{ij} = the core specific gravity for the jth tree at the ith location m_1 = number of trees at each location

n₁ = number of locations

- (b) The standard deviation of individuals was estimated from the sample range of the core specific gravities using the tabular values of the ratio of the **standard** deviation to the range.
- 7 Tree specific gravities were estimated from regression by:
 - (a) Tree specific gravity(Y) = $b_0 + b_1X_1 + b_2X_2$

where: Y = tree specific gravity

 X_1 = average specific gravity of 2 extracted cores

 $X_2 = d.b h./age$

(b) The standard error of the predicted mean tree specific gravity was estimated by--

$$\% = \begin{bmatrix} y. \frac{S^2}{N} \left(\frac{1}{m_2 n_2} + C_{11} (\overline{x}_{1,1} - \overline{x}_{1,2})^2 + C_{22} (\overline{x}_{2,1} - \overline{x}_{2,2})^2 + 2C_{12} (\overline{x}_{1,1} - \overline{x}_{1,2}) (\overline{x}_{2,1} - \overline{x}_{2,2}) \right) \\ \frac{S^2_y}{m_1 n_1} \sqrt{\frac{1}{2}} \end{bmatrix}$$

where: $S_{v,x}^2$ = residual mean squares

 S_{v}^{2} : variance of y prior to adjustment for regression

 $\ddot{x}_{1,1}$ mean core specific gravity of trees from which only cores were collected, sample (1)

 $\bar{x}_{1/2}$ = mean core specific **gravity** of trees collected for tree-core relationships, sample (2)

 $\overline{x}_{2,1}$ = mean d. b h /age for sample (1)

 $\overline{x}_{2,2}$ mean d b h /age for sample (2)

 m_1 number of trees at each location, sample (1)

m_a = number of trees at each location, sample (2)

n₁ : number of locations, sample (1)

n = number of locations, sample (2)

(c) The standard error of the core mean was approximated by the following computation when the variance were pooled to obtain the mean core specific gravity of more than one location:

standard error =
$$\sqrt{\frac{K}{(\Sigma n_i)^2}} \left(\frac{\Sigma S_i^2 + \bar{x}^2 \Sigma n_i^2 - 2\bar{x} \Sigma n_i S_i}{K - 1} \right)$$

- where: K = the number of locations at which trees were bored for specific gravity $S_i = \text{the sum of specific gravities of cores at the ith location (= <math>\Sigma_i X_{ij}$)}
- (d) When variances were not pooled the standard error of the mean was approximated by--

- where: S = standard deviation estimated from the sample range of core specific gravities n = number of observations in sample
- 8. Percentage difference in specific gravity due to extraction = $\frac{\text{unextracted core sp. gr.}}{\text{extracted core sp. gr.}} = \frac{\text{unextracted core sp. gr.}}{\text{extracted core sp. gr.}} \times 100$

Table 6.—Regression equations, correlation coefficients, coefficients of determination, and standard errors for Ocala sand pine increment core/tree specific gravity relationships

	Regression equations	r	r ²	Standard err or
F	regression equations			
Tree specific gravity (Y):		0.89	0. 79	0.020
Y = 0.23819 + 063621	(weighted sp. gr., 2 extracted cores) — 0.15399 (d.b.h./age) — 0.00277 (d.b.h.)	0.89	0. 79	0.020
Y = 0.16814 + 0.58458	(weighted sp. gr., 2 cores) — 0.06927 (merch. vol./age) + 0.00069 (age)	0.89	0. 79	0. 020
Y = 0.23253 + 0.63061	(sp. gr., outer $\frac{2}{3}$ of 2 extracted cores) $\frac{1}{3}$ 0.000250 (d.b.h.)	0.89	0. 79	0.019
Y = 0.17710 + 0.55341 Y = 0.11672 + 0.75 105	(sp. gr., outer 2/3 of 2 cores) — 0.06488 (merch. vol./age) + 0.00071 (age)	0. 88	0. 77	0. 020
Y = 0.20802 + 0.64408	(weighted sp. gr., 2 cores) 0.05899 (merch. vol./age)	0. 88	0. 77	0. 021
Y = 0.32667 + 0.71611	(sp. gr., outer 2/3 of 2 extracted cores) — 0.16113 (d.b.h./age) (sp. gr., outer 2/3 of 2 cores) — 0.05299 (merch. vol./age)	0. 88	0. 77	0.02 1
Y = 0.19236 + 0.71011	(sp. gr., 2 cores) — 0.09074 (merch. vol./age) + 0.00084 (age)	0. 88	0. 77	0. 020
Y = 0.26691 + 0.62005	(sp. gr., 2 extracted cores) $-$ 0.16832 (d.b.h./age) $-$ 0.00374 ((d.b.h.)	0. 88	0. 77	0. 021
Y = 0.24863 + 0.49905	(sp. gr., outer 1/3 of 2 cores) — 0.12002 (d.b.h./age) — 0.00058 (merch. vol.)	0. 88	0. 77	0. 021
Y = 0.21608 + 0.64057	(weighted sp. gr., 2 extracted cores) \rightarrow 0.17043 (d.b.h./age)	0. 87	0. 76	0. 021
Y = 0.23304 + 0.51868	(sp. gr., outer 1/3 of 2 cores) — 0.12107 (d.b.h./age)	0. 87	0. 76	0. 021
Y = 0.29657 + 0.50958	(sp. gr., 1 core) ~ 0.16497 (d.b.h./age) ~ 0.00394 (d.b.h.)	0. 87	0. 76	0. 021
Y = 0.28981 + 0.47028	sp. gr., outer $2/3$ of 1 core) $\rightarrow 0.15049$ (d.b.h./age) $\rightarrow 0.00261$ (d.b.h.)	0. 87	0. 76	0. 021
Y = 0.27504 + 0.51068	(weighted sp. gr., 1 core) — 0.14584 (d.b.h./age) — 0.00281 (d.b.h.)	0. 87	0. 76	0. 021
Y = 0.13273 + 0.75684	(sp. gr., 2 cores) — 0.08518 (merch. vol./age)	0. 86	0. 74	0. 022
Y = 0.31676 + 0.48044	(weighted sp. gr., 1 extracted core) - 0.18768 (d.b.h./age) - 0.00300 (d.b.h.)	0. 86	0. 74	0. 022
Y = 0.32674 + 0.49577	(sp. gr., 1 extracted core) — 0.19335 (d.b.h./age) — 0.00395 (d.b.h.)	0. 86	0. 74	0. 022
Y = 0.30818 + 0.46094	(sp. gr., outer $1/3$ of 2 extracted cores) -0.17661 (d.b.h./age) -0.00209 (d.b.h.)	0. 86	0. 74	0. 022
Y 0. 31697 + 0. 46886	(sp. gr., outer 2/3 of 1 extracted core) — 0.18738 (d.b.h./age) — 0.00281 (d.b.h.)	0. 86	0. 74	0. 022
Y = 0.06855 + 0.80901	(sp. gr., outer 2/3 of 2 cores)	0. 85	0. 72	0. 023
Y = 0.26222 + 0.56947		0. 85	0. 72	0. 023
Y = 0.25339 + 0.15320	(weighted sp. gr., 1 core) — 0.16267 (d.b.h./age)	0. 85	0. 72	0. 022
Y = 0.28129 + 0.48540	(sp. gr., outer 1/3 of 2 extracted cores) - 0.18545 (d.b.h./age)	0. 85	0. 72	0. 023
Y = 0.29534 + 0.47166	(sp. gr., outer $\frac{2}{3}$ of 1 extracted core) $-$ 0.20431 (d.b.h./age)	0. 85	0. 72	0. 023 0. 022
Y = 0.26601 + 0.47977	(sp. gr., outer $2/3$ of 1 core) -0.16456 (d.b.h./age)	0. 85 0. 84	0. 72 0. 71	0. 022
$\mathbf{Y} = 0.05421 + 0.85125$	(weighted sp. gr., 2 cores)	0. 84	0. 71	0. 023
Y = 0.29517 + 0.45357	(sp. g-r., 1 core) = 0.19764 (d.b.h./age)	0. 84	0. 71	0. 023
Y = 0.29764 + 0.47477	(weighted sp. gr., 1 extracted core) -0.20687 (d.b.h./age)	0. 84	0. 71	0. 023
Y = 0.35317 + 0.33339		0. 83	0. 69	0. 024
Y = 0.10027 + 0.73661 Y = 0.32596 + 0.43207	(sp. g-r., outer 1/3 of 2 cores)	0. 83	0. 69	0. 024
$\mathbf{Y} = 0.32514 + 0.35852$	(sp. gr., 1 extracted core) — 0.22388 (d.b.h./age) (sp. g-r., outer 1/3 of 1 core) — 0.17372 (d.b.h./age)	0. 83	0. 69	0. 024
Y = 0.37669 + 0.30488	(sp. gr., outer 1/3 of 1 cote) — 0.17372 (d.b.h./age) — 0.00065 (merch. vol.)	0. 83	0. 69	0. 024
Y = 0.36179 + 0.32489	(sp. gr., outer $1/3$ of 1 extracted core) $-$ 0.21737 (d.b.h./age)	0. 81	0. 66	0. 025
Y = 0.02762 + 0.96834	(sp. gr., outer $2/3$ of 2 extracted cores)	0.79	0. 62	0. 026
Y = 0.07598 + 0.81345	(weighted sp. gr., 1 core)	0. 77	0. 59	0. 027
Y = 0.09291 + 0.76550	(sp. gr., outer 2/3 of 1 core)	0. 76	0. 58	0. 027
Y = 0.02672 + 0.98552	(weighted sp. gr., 2 extracted cores)	0. 76	0. 58	0. 027
Y = 0.06759 + 0.85070	(sp. gr., 2 cores)	0. 76	0. 58	0. 027
Y = 0.15758 + 0.62566	(sp. gr., outer 1/3 of 1 core)	0. 73	0. 53	0. 029
Y = 0.09957 t 0.7965		0. 72	0. 52	0. 030
Y = 0.06341 + 0.93478		0. 68	0.46	0. 031
Y = 0.10591 t 0.77028	(sp. gr., 1 core)	0. 68	0.46	0. 031
Y == 0.11900 t 0.76519	(sp. gr., outer 2/3 of 1 extracted core)	0. 66	0.44	0. 032
Y = 0.11205 + 0.79290	(weighted sp. gr., l extracted core)	0. 65	0. 42	0. 032
Y = 0.18626 + 0.60863	(sp. gr., outer 1/3 of 1 extracted core)	0.59	0. 35	0. 034
Y = 0.15212 + 0.72256	(sp. gr., 1 extracted core)	0.57	0. 32	0. 035

Table 7.—Regression equations, correlation coefficients, coefficients of determination, and standard errors for Choctawhatchee sand pine increment core/tree specific gravity relationships

	coro del specific gravity relationships			
Regression	equations	r	\mathbf{r}^2	Standard error
Tree specific gravity (Y):				
	(weighted sp. gr., 2 cores) + 0.00058 (total height) - 0.07528 (d.b.h./age)	0.76	0.58	0.019
	(sp. gr., 2 extracted cores) + 0.01208 (total height/age) - 0.07933 (d.b.h./age)	0.76	0.58	0.019
Y = 0.13286 + 0.63717 (s	sp. gr., outer $2/3$ of 2 cores) $+$ 0.00067 (total height) $-$ 0.02309 (merch. vol.)	0.76	0.58	0.019
Y = 0.14315 + 0.74310 (v	weighted sp. gr., 2 extracted cores)	0.75	0.56	0.019
	(sp. gr., outer 2/3 of 2 cores)	0.75	0.56	0.019
	(weighted sp. gr., 2 cores) — 0.04144 (d.b.h./age)	0.75	0.56	0.020
	sp. gr., 2 extracted cores) — 0.05552 (d.b.h./age)	0.75	0.56	0.020
Y = 0.13074 + 0.74825 (v	weighted sp. gr., 2 extracted cores) + 0.00019 (total height)	0.75	0.56	0.020
Y = 0.12917 + 0.67696 (s	(sp. gr., outer $2/3$ of 2 cores) + 0.00022 (total height)	0.75	0.56	0.019
Y = 0.14328 + 0.71956 (v	weighted sp. gr., 2 extracted cores) + 0.00037 (total height) - 0.04045 (d.b.h./age)	0.75	0.56	0.020
	(sp. gr., 2 extracted cores)	0.74	0.55	0.020
Y = 0.15089 + 0.66158 (v	(weighted sp. gr., 2 cores)	0.74	0.55	0.020
	sp. gr., outer 2/3 of 2 extracted cores)	0.74	0.55	0.020
Y = 0.13916 + 0.72383 (s	(sp. gr., outer $2/3$ of 2 extracted cores) + 0.00017 (total height)	0.74	0.55	0.020
Y = 0.14988 + 0.69963	(sp. gr., outer $2/3$ of 2 extracted cores) + 0.00032 (total height) — 0.03215 (d.b.h./age)	0.74	0.55	0.020
Y = 0.20686 + 0.55197 (s	(sp. gr., 2 cores) + 0.00074 (total height) - 0.15249 (d.b.h/age)	0.72	0.52	0.021
Y = 0.18347 + 0.65460 (s	(sp. gr., 1 extracted core) + 0.00074 (total height) - 0.00252 (d.b.h.)	0.7 1	0.50	0.02 1
Y = 0.23834 + 0.54820 (s	(sp. gr., 2 cores) — 0.10984 (d.b.h./age)	0.70	0.49	0.021
Y = 0.20125 + 0.68069 (8)	sp. gr., 1 extracted core) — 0.00147 (d.b.h.)	0.69	0.48	0.021
$V = 0.23117 \cdot 0.0581 + 0.43776 $ (8)	(sp. gr., outer 1/3 of 2 cores) + 0.00075 (total height) - 0.00135 (d.b.h.)	0.68	0.46	0.022
+ 0.72651 (8	sp. gr., 1 extracted core)	0.67	0.45	0.022
Y = 0.24326 + 0.46630 (s	(sp. gr., outer $1/3$ of 2 cores)	0.67	0.45	$0.022 \\ 0.022$
Y = 0.21625 + 0.47955 (s	(sp. gr., outer 1/3 of 2 cores) + 0.00038 (total height) (sp. gr., 1 core) + 0.00073 (total height) — 0.12213 (d.b.h./age)	0.67	0.45	0.022
Y = 0.24007 + 0.47787 (8	(sp. gr., outer $1/3$ of 2 extracted cores) + 0.00066 (total height) - 0.02153 (merch. vol./age)	0.67	0.45 0.45	0.022
V 0.24909 + 0.40102 (8	(sp. gr., outer $1/3$ of 2 extracted cotes) + 0.00000 (total height) \longrightarrow 0.02133 (merch. vol./age) (sp. gr., outer $2/3$ of 1 core) + 0.00100 (total height) \longrightarrow 0.00259 (d.b.h.)	0.67 0.67	0.45	0.022
V - 0.22105 + 0.40972 (s	(sp. gr., outer 113 of 2 extracted cores) $+$ 0.00025 (total height)	0.66	0.44	0.022
v - 0.25014 ± 0.40972 (v	(weighted sp. gr., 1 core) + 0.00098 (total height) - 0.00256 (d.b.h.)	0.66	0.44	0.022
V = 0.23014 + 0.41073 (v	(sp. gr., outer 1/3 of 2 extracted cores)	0.66	0.44	0.022
Y = 0.20767 + 0.55582 (s	(sp. gr. 2 cores)	0.64	0.41	0.022
Y = 0.27102 + 0.47048 (s	(sp. gr., 1 core) — 0.08025 (d.b.h./age)	0.64	0.41	0.023
Y = 0.28251 + 0.42026 (s	(sp. gr., outer 2/3 of 1 core) — 0.00120 (d.b.h.)	0.64	0.41	0.022
	(weighted sp. gr., 1 core) 0.00119 (d,b,h,)	0.63	0.40	0.023
	(weighted sp. gr., 1 extracted core) + 0.00081 (total height) - 0.00237 (d.b.h.)	0.63	0.40	0.023
Y = 0.25050 + 0.45745 (s	(sp. gr., outer 2/3 of 1 extracted core) + 0.00084 (total height) - 0.00237 (d.b.h.)	0.62	0.38	0.023
	(sp. gr., outer 2/3 of 1 core)	0.62	0.38	0.023
Y = 0.23899 + 0.49636 (s	(sp. gr., 1 core)	0.61	0.37	0.023
Y = 0.25274 + 0.45823 (v	(weighted sp. gr., 1 core)	0.61	0.37	0.023
Y = 0.27071 + 0.49236 (v	(weighted sp. gr., 1 extracted core) 0.00121 (d.b.h.)	0.61	0.37	0.024
Y = 0.27238 + 0.48172 (s	(sp. gr., outer $2/3$ of 1 extracted core) $-$ 0.00117 (d.b.h.)	0.60	0.36	0.024
Y = 0.23779 + 0.53751 (v	(weighted sp. gr., 1 extracted core)	0.59	0.35	0.024
Y = 0.23935 + 0.52709 (8	(sp. gr., outer $2/3$ of 1 extracted core)	0.58	0.34	0.024
Y = 0.33900 + 0.22788 (§	(sp. gr., outer $1/3$ of 1 core) $+$ 0.00101 (total height) 0.00291 (d.b.h.)	0.56	0.31	0.025
Y = 0.37332 + 0.23890 (8	(sp. gr., outer 1/3 of 1 core) — 0.00148 (d.b.h.) (sp. gr., outer 1/3 of 1 extracted core) + 0.00094 (total height) — 0.00291 (d.b.h.)	0.52	0.27	0.025
		0.52	0.27	0.025
	(sp. gr., outer 1/3 of 1 core) (sp. gr., outer 1/3 of 1 extracted core) — 0.00155 (d.b.h.)	0.49	0.24	0.026 0.026
	(sp. gr., outer $1/3$ of 1 extracted core) \longrightarrow 0.00133 (0.0.11.)	0.49 0.45	$0.24 \\ 0.20$	0.026
1 = 0.34019 + 0.28389 ((op. gr., outer 1/3 or 1 extracted core)	0.43	0.20	0.020

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Sand pine (\underline{Pinus} \underline{clausa} (Chapm.) Vasey) was sampled at 35 different locations over its entire range. Specific gravity was determined for both unextracted and extracted increment cores. Increment core/tree specific gravity relationship8 were examined, and equations for predicting tree specific gravity were developed. Specific gravity data on the two races of sand pine--Ocala in eastern Florida and Choctawhatchee in western Florida--were analyzed separately, and differences between the two are discussed.

The average increment core specific gravity was .439 for the Ocala race and .485 for the Choctawhatchee race. Solvent extraction reduced specific gravity of increment core8 from Ocala sand pine to ,407, a difference of 7.86 percent. Extraction reduced the specific gravity of increment cores from Choctawhatchee sand pine from .485 to ,442, a difference of 9.73 percent. The estimated tree specific gravity was ,419 for Ocala sand pine and .482 for Choctawhatchee.

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